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The economic effects of energetic exploitation of straw in Vojvodina

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ABSTRACT

The autonomous province of Vojvodina is an autonomous province in the Republic of Serbia. It is located in the northern part of the country, in the Pannonia plain. Vojvodina is an energy-deficient province.

Assessment of the effects of energetic use wheat straw is performed for certain types of systems for storing straw and straw stored specifically in the form of small square bales, and especially for the cylinder-shaped straw bales. The method of evaluation of economic effects is based on the total cost of collecting, transportation, handling and storing, with corrections for the difference in the cost of the energy conversion and combustion.

With comparison of the costs of energy production from baled straw to the costs of energy production from hard coal, it was found that the energy obtained from the straw from own farm is cheaper than energy from hard coal by 28%, in the case of the using small square bales and by 34% in the case of the using cylinder-shaped bales. Through sensitivity analysis it was concluded that the two systems of collecting straw, economically, are relatively resistant to changes in prices of the most important inputs. However, there is a relatively high sensitivity to changes in performances of machines with a larger percentage increase of costs for the system with cylinder-shaped bales. However, this system is generally more resistant to changes of influencing factors due to lower basic costs per ton of the pretreated straw. Differential costs analysis, i.e., the development of differential calculations, shows that the energy from straw in the form of small square bales is cheaper than the energy from hard coal by 51%, while the energy from the straw in the form cylinder-shaped bales is cheaper by 60%.

Contents

1. Introduction

The autonomous province of Vojvodina is an autonomous province in the Republic of Serbia. It is located in the northern part of the country, in the Pannonia plain. Vojvodina is an energy-deficient province [1–4].

Assessment of economic effects of energetic use wheat straw is performed especially for combustion of baled straw, especially for the process of production of briquettes. The introduction of a new technological process does not induce effects on all operating costs, but mainly affects the increase in variable costs (in the case when the introduction of this process does not change the capacity

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or acquisition of new assets). Further analysis of the obtained solutions is performed by making differential calculations in which the bill emerging costs. Other expenses (which already had a farm) in the differential calculations are not calculated.

Assessment of the effects of energetic use wheat straw is performed for certain types of systems for storing straw and straw stored specifically in the form of small square bales, and especially for the cylinder-shaped straw bales. The method of evaluation of economic effects is based on the total cost of collecting, transportation, handling and storing, with corrections for the difference in the cost of the energy conversion and combustion [5].

As the primary method of evaluation of the economic effects of energy use straw collected by using both observed baling systems is performed by comparing energy prices obtained in this way, with the price of energy produced from conventional energy sources. Energy source with which the comparison was carried out was the hard coal. In accordance with the need to exclude from the comparison of the differences arising from different energetic values and combustion technologies, a comparison is performed by calculation of the price for 10 MJ of the obtained energy [6].

In previous studies, the economic comparisons were often related with the energetic use of crop residues on the level of raw materials for producing of energy. Recalculation to the same basis of comparison was performed by recalculation of costs of the energy with respect to the energetic values of raw materials [7]. The comparison conducted in this way does not take into account: (1) increased investments in equipment for combustion, (2) increase in the costs of combustion in the furnace, and (3) a lower efficiency. These aspects favor the straw as fuel.

2. Assessment of economic effects of energetic use baled straw

In line with earlier calculations conducted and the obtained results [8,9] it is possible to conclude the following. The energy generated by burning straw is cheaper than energy from hard coal. Costs of obtaining 10 MJ of energy from hard coal according to calculations amount to 30.8 €. In the case of combustion of small square bales, the price of the same energy quantity from straw is 22.1 € and 20.4 € for a previously unfolded round bales. Therefore, at the use of straw, heating costs are reduced by 28.1% in the case of use small square bales, or 33.6% in the case of using round bales.

One of the objections that can be given for the performed calculation can refer to the omission of calculating interest on assets employed. This interest is related to the assets that the company engages in the process of collection of straw through their integration in the total costs. In fact, during the collection and pretreatment of the straw a company blocks its funds. The average period of blocking of assets can be estimated on the basis of the moment of harvesting of the straw from the pitch and duration of the heating season. If the month of July is determined as a period of the beginning of process of collecting, and the month of April as the end of the heating season, it is possible to conclude that the engagement of fundings lasts ten months. In earlier calculations, we used the interest rate of 6% per annum, so that for a period of ten months it amounts to 5%. The dynamics of engagement of fundings and their release can be evaluated with the assumption that the average amount of funds involved is about 50% of total assets. Based on these factors, it can be estimated that the cost of the engaged capital amounts to 0.9 €/t in the case of small square bales, or 0.8 €/t in the case of cylinder-shaped bales. It is obvious that the inclusion of these values in the calculation does not to the higher degree change the previously presented results [8,9].

As a second stage in assessing the economic effects of energetic use of baled wheat straw, it is necessary to perform the calculation of time of return of investments. This calculation can assume two hypothetical situations: (1) decision to build a new furnace, where the selection must be done between a classical fireplace and a fireplace for the baled straw and (2) decision to replace an existing fireplace for combustion of coal with a fireplace for combustion of the baled straw.

In the first case, a comparison between the costs of these two systems designed at the same capacity is performed when looking at return on increased investment resulting from an election furnace for combustion of baled straw. The second case not only compares the total running costs but also follows the return of total investments in plant for combustion of straw. Discounted results during the years of exploitation were performed with the interest rate of 6%.

According to accounts given to investments in previous works [8,9], total investments in plant for combustion of straw amounted to 33,720 €, and investments in plant for coal combustion to 25,380 €. Increase of investments in the case of construction of the plant for burning of straw is 8340 €, and the refund is calculated for this amount. In the calculation of the annual costs for the plant, which includes the cost of fuel and operating costs, it was found that those in the case of combustion plants amounted to 38,831 € of straw, and in the case of plants for combustion of coal they amounted to 76,592 €. Therefore, the savings on an annual basis, in the case that the company builds a plant for combustion of straw, are 37,760 € [10–13].

3. Assessment of economic effects of energetic exploitation of straw briquettes

Briquetting technology is used as an attempt to determine the possibility of market realization of straw as fuel for combustion. In the briquetting process, straw is compressed, whereby the bulk density of about 500 kg/m^3 is achieved. This induces briquettes characteristics, which are closer to the characteristics of firewood, so that the comparison was performed with wood as an alternative energy source. Transportation, i.e., bulk density of wood ranges from 400 kg/m^3 to almost 700 kg/m^3. This depends largely on the degree of moisture content, with the greater weight does not mean the higher energy value, but, as a rule it is, rather the lower one. Energy value and the bulk density of wood vary depending on the type of wood.

The wood density is also estimated using data from previous table to about 500 kg/m^3. Based on these factors it is possible to perform parallel relationships in which 1 t of briquettes are replaced with 2 m^3 of wood. This comparison is necessary to do so due to the fact that market turnover, and thus the pricing of wood, has to be performed by calculation of the price for transportation volume of 1 m^3. Market price of 1 m^3 of wood on the account day in the market is in an average of around 28.7 €. If this value is compared with the price of production of 500 kg of briquettes, which, according to calculations conducted was 36.1 € and to the obtained value, the tax for the increased value to tax at a rate of 18% was added, results the amount of about 42.5 €. Accordingly, it is possible to draw conclusions about the uneconomical production of straw briquettes.

In fact, this high cost of production does not leave room to cover the basic costs of production, let alone the profit. In addition, the briquettes because of their low moisture resistance, and because of this the need of their packaging, complex handling and storage. In this way, the costs of their distribution in the market are still further increased. The main reason for this high level of costs is the high cost of briquetting. Briquetting costs can be reduced through the construction of larger capacity that is powered by electricity. However, the production of briquettes in this way raises the problem of

maintaining the amount of straw needed for increased utilization of plant capacity. This again reflects on the uneconomical transportation of straw to greater distances, and its absence from the market turnover.

4. Sensitivity analysis of the costs of energetic exploitation of straw

Sensitivity analysis should give an answer about changing the cost in terms of significant value changes or technical–technological parameters of the production process. The application of this method requires as the first step the application of "Pareto" principle, when parameters that are important for the economic effects of exploitation have to be defined. In the second step, sensitivity analysis gives an analysis of the intensity changes of the total costs, depending on the changes of the defined parameters of the analyzed process. Sensitivity analysis of costs is derived from two basic reasons. Firstly, the sensitivity analysis is a valuable aid in the operative planning, because the obtained results can effectively help the prediction and monitoring of the costs and their changes, and in this way induce the improvement of overall business results. In addition, this analysis should serve to reach a conclusion about the security solutions that are defined in the calculations and plans. In this way it is possible all technical and technological solutions to test in the variable conditions and check the influence of changes of essential factors of the observed process on changes of the costs. For interpreting the results of sensory analysis of costs, it is very important to know the probabilities of changes of the tested factors and to interpret the results accordingly. As for the process of energy exploitation of straw, defining the factors influencing the cost structure is performed on the basis of the structure of costs obtained in the previous part of the paper.

Sensitivity analysis is done in case of change (increase or decrease) of price of fuel and engine oil, interest rates, earning full-time employees, seasonal wages of casual workers, and the outputs achieved.

Testing of the results obtained by sensitivity analysis is performed assuming that the costs of these elements increase by 30%. These changes of 30% were selected for the purpose of presenting the impact of significant changes in production costs. Model for the calculation of costing, used in this paper, is able to perform sensitivity analysis for any defined change in costs or effects. In accordance with the nature of costs and their relations, the analysis is conducted in three separate parts: (1) changes in prices of fuel and motor oil, (2) change the interest rates, (3) changes in permanent employees salaries and wages, and wages of seasonal and casual workers, including the changes of pretreatment and combustion processes and (4) changes in the outputs achieved, with the changes applied only to the processes of pretreatment of crop residues.

4.1. Impact of changes in prices of fuels and lubricants

Impact of changes in prices of fuel and engine oil was analyzed by assuming price growth of 30%. With this, the fuel price increases with a relatively high price at the time of settlement, of about 1.1–1.4 €/l and the price of oil from 1.8 € to 2.3 €/l. The total cost of collecting straw in small square bales are increased by 8.91% to 20.1 €/t of baled straw. In addition, the costs of obtaining 10 MJ of energy are increased by 7.7% to 23.8 € (Table 1).

It is obvious that the highest growth achieved transportation costs, while the costs of materials, loading and manipulation do not increase because these operations do not consume motor fuel. Even at such a rise in the costs of energy, obtained by combustion of small square bales, it is 22.6% cheaper than energy from hard coal. Changes in costs are not recorded in the operations of loading and manipulation, because they are performed manually.

Table 1
Increase in costs of pretreatment and energetic utilization of straw stored in small square bales.

Costs	The costs of the base solution (€/t)	Cost of the test solution (€/t)	Increase in costs (%)
Baling	4.3	4.7	10.3
Materials	1.9	1.9	0.0
Loading	1.2	1.2	0.0
Transportation	5.4	6.2	14.9
Manipulation	1.2	1.2	0.0
Storage	2.8	3.0	8.9
Baled straw, total costs	16.8	18.3	8.9
Costs of obtaining 10 MJ of energy, €	20.1	21.7	7.7

In the same way the costs of collecting system of straw in the form of cylindrical bales were analyzed. When increasing the price of fuel and engine oil by 30%, they increase by 13.8% to 0.2 €/t of baled straw. In addition, the costs of obtaining 10 MJ of energy increase by 11.7% to 22.8 € (Table 2).

With such increase of costs, the energy provided by burning bales is 25.8% cheaper than energy from hard coal. In the present case, only the cost of materials did not achieve growth. Total growth is greater than the increase in costs when using the system of small cylinder-shaped bales, but the results are still favorable.

4.2. Impact of interest rate changes

Impact of interest rate changes was also analyzed assuming growth of 30%. With this increase, the interest rate increases from 6.0% to 7.8%. The total costs of collecting straw in small square bales are increased by 1.8% to 18.8 €/t of baled straw. In these conditions, the cost of obtaining 10 MJ of energy is increased by 2.1% to 22.6 € (Table 3).

With such increasing of costs of energy provided by burning small square bales, it is 26.8% cheaper than energy from hard coal. The highest growth was achieved in the baling operation, since it needs the provision of the high cost machinery.

Analysis of interest rate increase by 30% in the case of cylinder-shaped bales and causes an increase in costs of pretreatment of straw by 2.1%, and they now amount to 17.2 €/t of baled straw. In this situation, costs of obtaining of 10 MJ energy are increased by 2.4% to 20.9 € (Table 4).

In this case, the energy provided by burning cylinder-shaped bales still remains 32.2% cheaper than energy from the hard coal, although it is obvious that this technology is due to greater engagement of techniques more sensitive to changes in interest rates.

Table 2
Increase in costs of pretreatment and energetic utilization of straw in the form of cylindrical bales.

Costs	The costs of the base solution (€/t)	Cost of the test solution (€/t)	Increase in costs (%)
Baling	4.4	4.9	12.6
Materials	0.6	0.5	0.0
Loading	5.4	6.2	15.2
Transportation	1.1	1.3	16.9
Manipulation	1.4	1.6	14.5
Storage	2.5	2.9	13.8
Baled straw, total costs	15.3	17.4	13.8
Costs of obtaining 10 MJ of energy, €	18.6	20.7	11.7

Table 3
Increase of costs of pretreatment and energetic utilization of straw collected in the system of small square bales.

Costs	The costs of the base solution (€/t)	Cost of the test solution (€/t)	Increase in costs (%)
Baling	4.3	4.4	2.9
Materials	1.9	1.9	0.0
Loading	1.2	1.2	0.0
Transportation	5.4	5.5	2.2
Manipulation	1.2	1.2	0.0
Storage	2.8	2.9	1.8
Baled straw, total costs	16.8	17.1	1.8
Costs of obtaining 10 MJ of energy, €	20.1	20.5	2.1

Table 4
Increase of costs of pretreatment and energetic utilization of straw bales collected by using the cylinder shaping system.

Costs	The costs of the base solution (€/t)	Cost of the test solution (€/t)	Increase in costs (%)
Baling	4.4	4.5	2.7
Materials	0.5	0.5	0.0
Loading	5.4	5.5	1.9
Transportation	1.0	1.1	1.5
Manipulation	1.4	1.5	2.2
Storage	2.5	2.6	2.1
Baled straw, total costs	15.3	15.6	2.1
Costs of obtaining 10 MJ of energy, €	18.6	19.0	2.4

The highest growth is also achieved for the baling expenses, as the performing of these operations employ machines with the highest values.

4.3. Impact of changes of wages of full time workers and of seasonal workers fees

The next analysis refers to the salary increase for full-time employees and the fees of seasonal or contingent workers. It is anticipated that wage increases by 30% and changes in the costs with using small square bales are given in Table 5.

As can be seen, the total costs of pretreatment straw in small square bales are increased by 7.5% to 19.8 €/t of baled straw. In this case, costs of obtaining 10 MJ of energy are increased by 8.2% to 23.9 €, and the energy provided by burning small square bales is now 23.2% cheaper than energy from the hard coal. Due to the manual loading and manipulation, growth of this category of costs is equal to the projected increase.

Table 5
Increase of costs of pretreatment and energetic utilization of straw collected in the form of small square bales.

Costs	The costs of the base solution (€/d)	Cost of the test solution (€/d)	Increase in costs (%)
Baling	4.3	4.4	3.1
Materials	1.9	19	0.0
Loading	1.2	1.5	30.0
Transportation	5.4	5.6	3.9
Manipulation	1.2	1.5	30.0
Storage	2.8	3.0	7.5
Baled straw, total costs	16.8	18.0	7.5
Costs of obtaining 10 MJ of energy, €	20.1	21.7	8.2

Table 6
Increase of costs of pretreatment and energetic utilization of the straw bales collected by the cylinder bales collecting system.

Costs	The costs of the base solution (€/d)	Cost of the test solution (€/d)	Increase in costs (%)
Baling	4.4	4.5	1.8
Materials	0.5	0.5	0.0
Loading	5.4	5.6	4.1
Transportation	1.0	1.1	4.5
Manipulation	1.4	1.5	3.9
Storage	2.5	2.6	3.1
Baled straw, total costs	15.3	15.8	3.1
Costs of obtaining 10 MJ of energy, €	18.6	19.4	4.5

When the same analysis applied to the system with the cylinder-shaped straw bales (Table 6), the costs of pretreatment are increased by 3.1% to 17.3 €/t of baled straw. In this situation, the costs of obtaining 10 MJ of energy are increased by 4.5% to 21.4 €.

The energy generated by burning cylinder-shaped bales in this case is 31.4% cheaper than the energy from the hard coal. It is obvious that the system of cylinder-shaped bales from the economic aspect is much less sensitive to change of wages due to lower engagement of the labor.

4.4. Impact of changes of efficiencies in the pretreatment process of straw

Sensitivity analysis can also be used to test the technological characteristics of the observed processes, and to analyze changes in economic indicators, depending on the impact of changes in the technological process. The work was carried out to estimate effects of costs changes, dependent on the defined performance standards of motor- and receptacle machines. According to the model already stated, the projected reduction of the effects was 30%, so that the standards used now amount to 70% of the standards used in the base solution. Reduction standards were applied to the overall technological process, where the norms were linearly decreased for all operations of the process of the straw pretreatment. Linear reduction was applied because of the fact that the observed process was interlinked and the overall performance is based on the performance of the weakest points of the process. Reduction of standards was not done for the combustion process, since that process takes place in the controlled conditions and is not subject to environmental influences. Testing the effects of changes was performed only in the case of reduction, while the basic calculations were performed for optimal conditions that are achieved under field conditions.

At the projected changes, the total costs of collecting straw in the form of small square bales are increased by 37.1% to 25.3 €/t of baled straw. In this case, the costs of obtaining 10 MJ of energy are increased by 31.8% and amounted to 29.2 € (Table 7).

With these changes in efficiency of machines, the energy provided by burning small square bales, is now 5.2% cheaper than energy from the hard coal, so that the reduction of the effects more than 30% can be considered as border size at which it was possible to preserve the efficiency of the process.

Changes in the costs at the decreased performance of 30%, in the case of collecting of straw with the system of cylindrical bales are given in Table 8. For the system cylindrical bales, straw pretreatment costs increase by 41.1% to 23.7 €/t. Costs of obtaining 10 MJ of energy are increased by 34.9% to 27.6 €.

With these changes of the efficiencies, the energy provided by burning the cylinder-shaped bales is still for 10.4% cheaper than the energy from the hard coal. It is obvious that the increase of costs

Table 7
Increase of costs for pretreatment and energetic utilization of straw collected in the form of small square bales.

Costs	The costs of the base solution (€/d)	Cost of the test solution (€/d)	Increase in costs (%)
Baling	4.3	6.2	42.8
Materials	1.9	1.9	0.0
Loading	1.2	1.7	42.9
Transportation	5.4	7.3	42.9
Manipulation	1.2	1.7	42.9
Storage	2.8	3.8	37.0
Baled straw, total costs	16.8	22.9	37.0
Costs of obtaining 10 MJ of energy, €	20.1	26.5	31.8

per unit of output for all operations that have been tested identical, as in the case of small square bales, is 42.9%. However, better results of the basic results for the system of cylinder-shaped bales contribute to the conservation of the process economics. Further testing revealed that only a reduction in efficiency of drive- and of receptacle machines for more than 40% induces the jeopardizing of the economy of this process.

As a final conclusion of the sensitivity analysis, it can be stated that the two systems of collection, economically, are relatively resistant to changes in prices of the most important inputs. On the other hand, there exists a relatively high sensitivity to the changes of efficiency drive- and receptacle machines, with a larger percentage increase of costs for the system of cylinder-shaped bales. However, this system is generally more resistant to changes of the influencing factors due to the higher reserves and lowers the basic costs per ton of the pretreated straw.

5. Differential cost analysis of energetic exploitation of straw

Differential cost analysis of the energetic use of straw is done through the development of differential calculations. By differential calculation, it is determined whether changes in the organization or business holdings are economically viable. It can be changes in production volume or change production methods.

The fact that the economic aspects of individual changes in agriculture, the most complete and with the best quality, can be analyzed using differential calculations is caused by two facts. The first is a close relation between all types of farming, so that the consequences of any changes include a larger number of production and cannot be adequately observed by the use of analytical calculations. In addition, agricultural enterprises dominate resources that are used for multiple lines of production. As another important fact, the existence of a high proportion of fixed costs in total costs is pointed out. So, if you look at the process of introducing technology for energy exploitation of straw for the examined farms, the estimation of effects for the overall operations should not be based on the application of analytical calculations, which is used for determination of total costs.

Table 8
Increase in costs of pretreatment and energetic utilization of straw bales collected by the cylindrical bales system.

Costs	The costs of the base solution (€/d)	Cost of the test solution (€/d)	Increase in costs (%)
Baling	4.4	6.3	42.9
Materials	0.5	0.5	0.0
Loading	5.4	7.7	42.9
Transportation	1.0	1.4	42.9
Manipulation	1.4	2.0	42.9
Storage	2.5	3.6	41.1
Baled straw, total costs	15.3	21.6	41.1
Costs of obtaining 10 MJ of energy, €	18.6	25.1	34.9

In order to reach more accurate results of the effects of such changes on the company, it is necessary to perform cost analysis, or to recognize changes in the case of the introduction of energetic utilization of straw. In the first phase of this analysis it is necessary to determine the needs for acquisition or construction of new fixed assets. The calculation of depreciation costs, interest, insurance and housing is performed only for newly acquired assets. Calculation of other cost categories is done according to standard methods set forth in the earlier part of the paper. In addition, costs of labor are done only for the costs of seasonal workers, as permanent staff salaries are a fixed cost category. To assure the correctness of this calculation, the costs of wages must include costs of permanent employees, if the introduction of technology requires and the employment of additional permanent worker. The calculation of the costs of materials is carried out according to the standard procedure, during which including only the direct costs of materials used. Costs of energetic conversion of crop residues should be viewed through the costs of modification of existing or uprising of new furnaces. Rating benefits of the technology are done in a simple manner. Namely, it is determined through energents savings in procurement that are substituted through the process of energetic utilization of crop residues or straw.

In this way, in addition to determining the economic results of such technology, comparative analysis of alternative technical and technological opportunities for exploitation of straw, or the calculation of differential costs for individual systems of the pretreatment of straw can be performed.

When making differential calculations it is assumed that the examined companies in the process of introduction of energetic utilization of straw buy only briquetting press and its expenses are calculated as a whole. Since it is assumed that the company has other operating and related machines, their differential costs are calculated separately for fixed and variable costs according to the following model: the depreciation costs are not accounted as represent the fixed costs, interest costs are also not calculated, maintenance costs are calculated as 60% of the budgeted costs, costs of fuel, motor oil, gear box oil and lubricants, and tire costs are calculated on the whole, the costs of insurance, housing, costs of taxes and fees are not charged.

Wages are calculated after their separation in fixed costs of permanent manpower, which are not calculated, since it is supposed that the company owns reserve of capacities of operating and receptacle machine tools, while the costs of seasonal workers are included in the calculation of the whole amount.

Costs of combustion in the case of the coal plants are not accounted, but they include only the correction for losses during burning. For a plant for combustion of straw costing is done in terms of total costs, where labor costs, or earnings, are omitted.

Differential cost analysis, performed according to these rules in the case of collection of straw in the form of small square bales, is given in Table 9.

In this way, the calculated differential energy costs obtained when using small square bales are lower than the previously presented results and amount to 12.2 €/10 MJ of the energy obtained (Table 10). It is important to note that in this case the word goes not about total costs, but they represent only the increase compared to the basic solution, i.e., the heating by coal, where the costs of obtaining an equivalent amount of energy are 14.4 €.

If the same method applied to the collection system cylinder-shaped bales, the obtained results are consistent with the earlier results (Table 11).

Table 9
Calculation of differential costs of energetic use of straw prepared in the form of small square bales.

Costs	Costs (€/t)	Costs structure (%)
Baling	1.9	17.5
Materials	1.9	17.2
Loading	1.2	10.6
Transportation	3.0	27.3
Manipulation	1.2	10.6
Storage	1.8	16.7
Total costs	11.1	100

Table 10
Calculation of differential prices for energy produced by burning small square bales.

Description	Unit	Value
Price of straw	€/t	11.1
Costs of combustion (corrected)	€/t	6.1
Total cost of obtaining of energy	€/t	17.1
Energetic value of fuel	kJ/t	119.1
Costs of obtaining 10 MJ of energy	€	13.1

Table 11
The calculation of differential cost when straw was collected in the form of cylinder-shaped bales is used.

Costs category (operations)	Costs (€/t)	Costs structure (%)
Baling	2.3	26.3
Materials	0.5	5.9
Transportation	3.1	35.2
Manipulation	0.6	7.2
Unwinding	0.8	8.7
Storage	1.4	16.7
Total costs	8.7	100

Table 12
Differential prices for energy produced by burning cylinder-shaped bales.

Description	Unit	Value
Price of straw	€/t	8.7
Costs of combustion (corrected)	€/t	5.2
Total cost of obtaining of energy	€/t	13.9
Energetic value of fuel	kJ/t	119.1
Costs of obtaining 10 MJ of energy	€	10.7

In this way, the calculated differential costs of the obtained energy when using the system of cylinder-shaped bales are lower than the previously presented results and amount to 9.6 €/10 MJ of the energy obtained (Table 12).

This is significantly below the costs of obtaining energy by burning the hard coal, although these costs include only the cost of purchased coal and combustion losses. Cost of producing 10 MJ of energy from hard coal is 29.5 €, whereas the energy from straw in small square bales is cheaper by 51.2%, and energy from straw bales in cylinder shape by 60.3%.

Calculation of differential cost of briquettes production shows that the additional costs amount to 44.6 €/t (Table 13). In this calculation briquettes production becomes profitable, because when the production costs is increased by 18% VAT and profit margin of about 10%, the sales price is higher than the selling price of wood for fuel (for the previously established parities).

Table 13
Differential costs of briquetting per ton of briquettes produced.

Description of costs	Costs (€/t)	Structure (%)
Straw	8.7	21.5
Briquetting	21.7	53.5
Packaging	3.6	8.9
Storage	6.5	16.1
Total	40.5	100

The outlined analysis indicates the additional benefits of using straw as an energy source. With this statement, it is important to know that the differential calculation and determination of differential costs are not omnipotent. When making differential calculations, the analysis of changes that depend only on the characteristics of household and type of change is performed. Calculation, which is presented above, represents a rather optimistic assumption. Namely, the same was done for the household, which has a high level of equipment operating and receptacle machines, and a certain reserve of unused capacity. Favorable result that was found when using this calculation mainly represents the result of use of hidden reserves of the capacity of businesses and neutralization of hidden losses that are consequences of the nonutilization of crop residues.

6. Conclusion

Assessment of economic effects of energetic use of straw is performed for straw collected in the form of small square bales and cylinder-shaped bales. The first system of small square bales is particularly suitable because of its large presence on the ground and advantages for use on small farms, which are dominant in Vojvodina. The system of cylinder-shaped bales shows undoubtedly technological advantages and a tendency of spreading on farms in Vojvodina. As a technology that should serve for the assessment of opportunities of straw energy that is closer to the market transactions, it is possible to use a briquetting technology. For the most rational use briquetting, a technique of already baled straw is at most convenient, with briquetting performed with the mobile briquetting machine.

The calculation of costs showed that the costs of pretreatment of 1 t of wheat straw collected as small square bales is approximately 22.5 €. Pretreatment of the same amount of straw collected with the cylinder-shaped baling system can be done at lower costs. In doing this costs per ton of pretreated straw amount to 20.5 €. When the above-discussed systems are used for pretreatment of crop residues intended for energy production, with small square bales, it is possible to produce 10 MJ at a cost of 27.0 €. Using the system of the cylinder-shaped bales same amount of energy can be produced at a cost of 24.9 €. Briquette production system with semistationar briquetting unit for collection of raw materials typically uses one of these systems. If, as a source of raw material, cylinder-shaped bales are used, production of 1 t of briquettes is possible at a cost of 87.9 €/t.

With comparison of the costs of energy production from baled straw to the costs of energy production from hard coal, it was found that the energy obtained from the straw from own farm is cheaper than energy from hard coal by 28%, in the case of using small square bales and by 34% in the case of using cylinder-shaped bales. Through sensitivity analysis it was concluded that the two systems of collecting of straw, economically, are relatively resistant to changes in prices of the most important inputs. However, there is a relatively high sensitivity to changes in performances of machines with a larger percentage increase of costs for the system with cylinder-shaped bales. However, this system is generally more resistant to changes of influencing factors due to lower basic costs per ton of the pretreated straw. Differential costs analysis, i.e., the development of differential calculations, shows that the energy from straw in the form of small square bales is cheaper than the energy from hard coal by 51%, while the energy from the straw in the form of cylinder-shaped bales is cheaper by 60%.

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